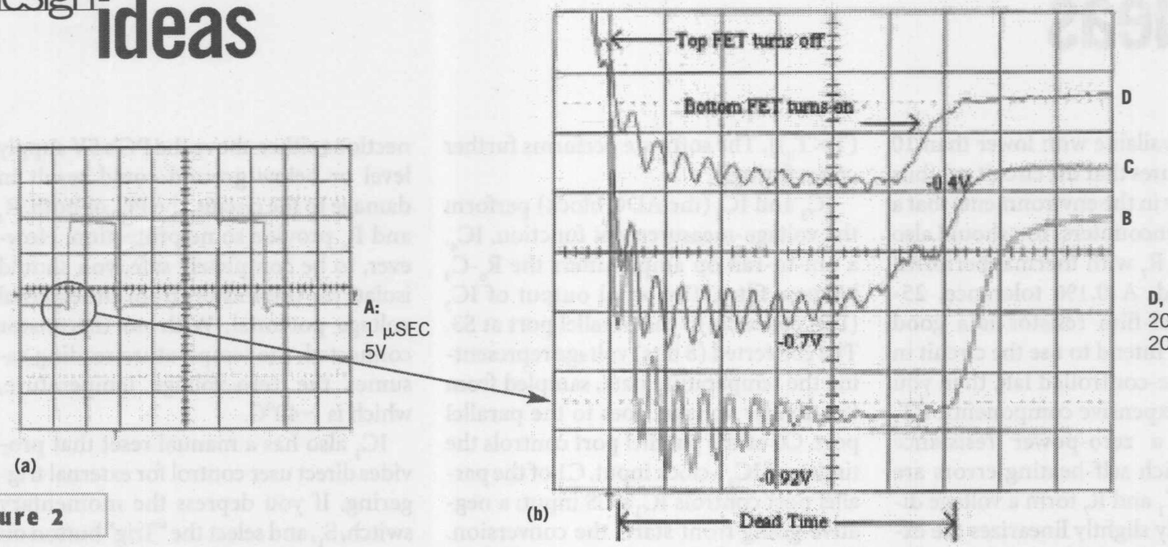

Figure 2

Expanding the dead-time waveforms (a) leads to three scenarios (b): the unadorned buck regulator (Trace B), adding a Schottky diode (Trace C), and the simple solution in Figure 3 (Trace D).

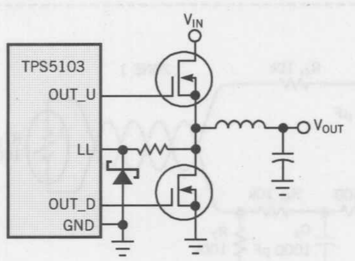

Figure 3 **Moving one resistor and adding a small Schottky diode minimizes the phase-node voltage.**

The circuit in **Figure 3** is small and inexpensive and significantly reduces the phase-node voltage at the control IC. The gate-drive resistor moves from the gate to the source of the top FET. Following the current from the IC as it charges and discharges the gate capacitance of the top FET shows that moving the resistor has no effect on the circuit operation. An SOT-23 or an SOD-123 Schottky diode with a current rating of 0.5A connects to the control IC. As you can see in Trace D of **Figure 2b**, when the voltage across the FET's body diode goes to −1V, the Schottky diode clamps the voltage on the IC to approximately −0.3V. The full output current flows through the FET, and the gate-drive resistor limits the current through the Schottky diode. This solution is small and inexpensive and prevents erratic operation or damage to the power-supply control IC.

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Track multisite temperatures on your PC

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THE LOW-COST CIRCUIT in **Figure 1** allows you to track four remote temperatures with thermistor sensors through the parallel port on your PC. This four-zone thermometer instrument has a temperature range of −40 to +90°C and a resolution of better than ±1°C. You can calibrate its accuracy to within 1°C over a 0 to 50°C span and within 3°C over a −40 to +90°C span. Thermistors are low-cost, passive, rugged components, making them a good choice for temperature sensing. The signal-conditioning hardware in **Figure 1** performs a simple voltage division to partially linearize the thermistors. Temperature data in the form of thermistor voltages goes into Excel macros, and software performs a fifth-order-equation fit using calibration coefficients to convert the data into Celsius temperatures. This Design Idea focuses on the electronics in Zone 1; the other zones behave similarly. You can implement one, two, three, or all four zones without software modification.

All components have low power (quiescent current) consumption to minimize LPT1 sourcing requirements. Four LPT1 outputs at D0 (Zone 1), D2 (Zone 2), D4 (Zone 3), and D6 (Zone 4) power this application. The hardware typically requires less than 162 µA of current per zone. Parallel-port drivers within your PC generally source at least 400 µA. Supervisory circuit IC_1 monitors the voltage from the LPT1 port. The reset output signal of IC_1 goes back to the parallel port at S7 for software error-checking at initialization. The software ascertains that the hardware is present and that the minimum voltage from D0 of the LPT1 port is greater than approximately 4.65V. Most PCs have a 5V parallel-port interface, but a few have only 3.3V available. For 3.3V PCs, you need to scale the voltage options of the components you use.

IC_2 is a voltage reference for both the RT_1-R_7 voltage divider and the ADC, IC_3. Inasmuch as IC_2 is common to the divider and the ADC, you obtain accurate ratiometric analog-to-digital conversion, and gain, offset, and thermistor-interchangeability errors are at a minimum. The low temperature coefficient of IC_2

(grades are available with lower than 10 ppm/°C) ensures that the circuit exhibits high accuracy in the environments that a portable PC encounters. You should also select R_4 and R_7 with thermal performance in mind. A 0.1% tolerance, 25-ppm/°C metal-film resistor is a good choice. If you intend to use the circuit in a temperature-controlled lab, then you can use less expensive components. RT_1 operates in a zero-power resistance mode, in which self-heating errors are negligible. RT_1 and R_7 form a voltage divider that only slightly linearizes the exponential equation of the NTC thermistor's negative-resistance-versus-temperature relationship: $R_T = R_{T0}\exp[(T_0 - T)/(T \times T_0)]$. The software performs further curve fitting.

IC_3 and IC_4 (the ADC block) perform the voltage-measurement function. IC_4, a rail-to-rail op amp, buffers the R_6-C_3 lowpass filter. The serial output of IC_3 (D0) connects to the parallel port at S3. The converted (8 bits) voltage representing the temperature data, sampled from the divider voltage, goes to the parallel port. C0 of the parallel port controls the timing of IC_3's clock input. C1 of the parallel port controls IC_3's CS input; a negative-going front starts the conversion. Resistors R_1, R_2, and R_3 help provide the logic interface between IC_3 and the parallel port. Pulling the thermistor connections either above the PC's 5V supply level or below ground could result in damage to the circuit, the PC, or both. R_4 and R_6 provide some protection. However, to be completely safe, you should isolate the thermistors from any external voltage potential. With no thermistor connected, the temperature reading assumes the zero-voltage temperature, which is −40°C.

IC_1 also has a manual reset that provides direct user control for external triggering. If you depress the momentary switch, S_1, and select the "Trig" button on the user form, then the circuit performs a temperature measurement. The hardware turns off when the user form clos-

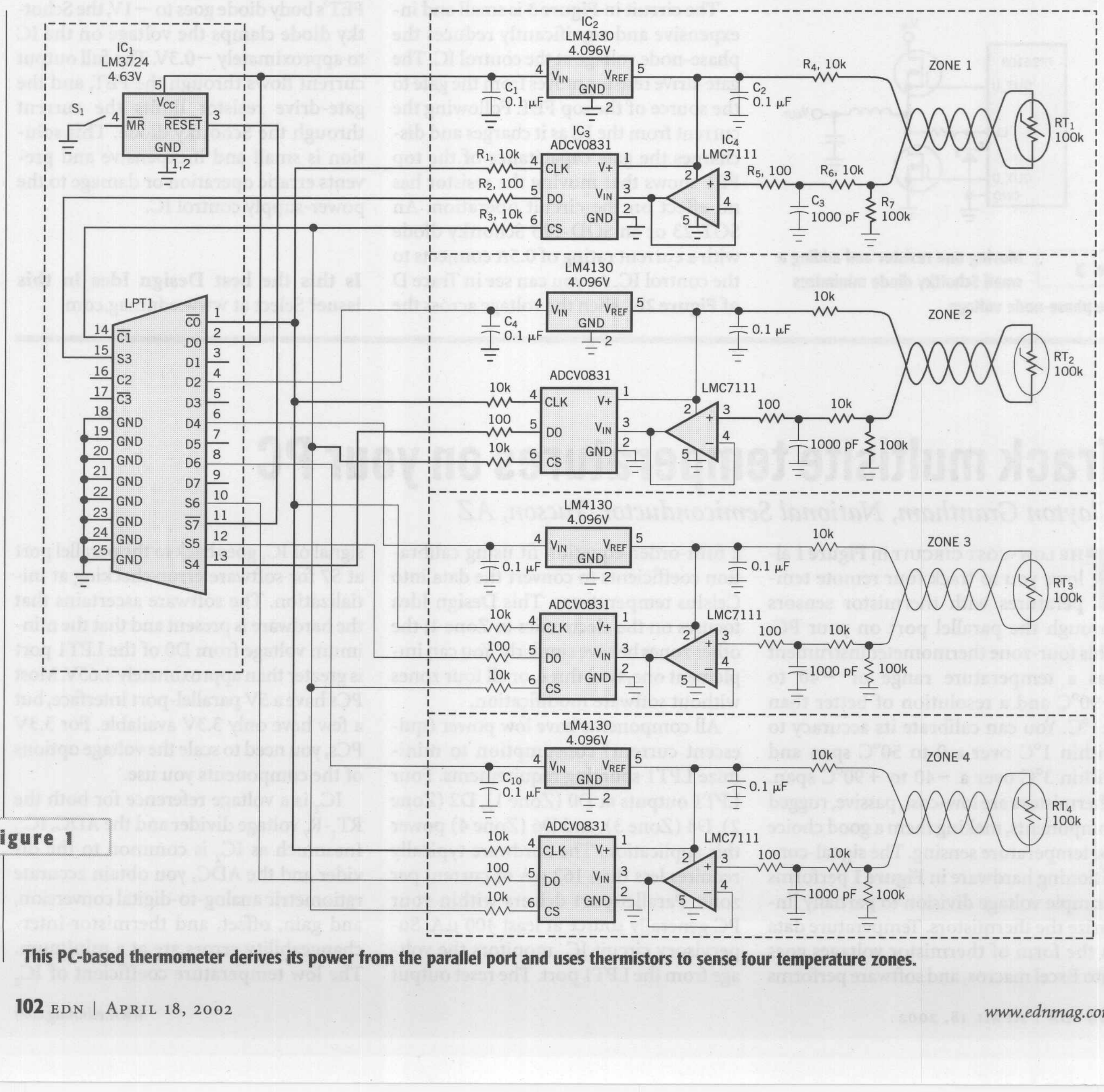

Figure 1

This PC-based thermometer derives its power from the parallel port and uses thermistors to sense four temperature zones.

es. The program control resides in Excel (running under Office 2000) macros that perform I/O through the LPT1 port of the PC. The program uses a free file "Input32.dll" to bit-wise-control the parallel port's digital I/O. The author of the .dll file is Jonathan Titus, editorial director of *Test and Measurement World*. You load QuadZone.xls with its macros, connect the circuit of **Figure 1** to the parallel port, and then run the *ControlPanel* macro. A user form (**Figure 2**) pops up, overlaying the spreadsheet, and connects temperature-measurement actions with the electronics. Your possible options using the user form are single-temperature measurement, multiple-temperature measurements separated by user-defined time intervals, linked measurements that append the data to an Excel spreadsheet, and externally triggered single-temperature measurements. You can download the spreadsheet and the .dll file from the Web version of this Design Idea at www.ednmag.com.

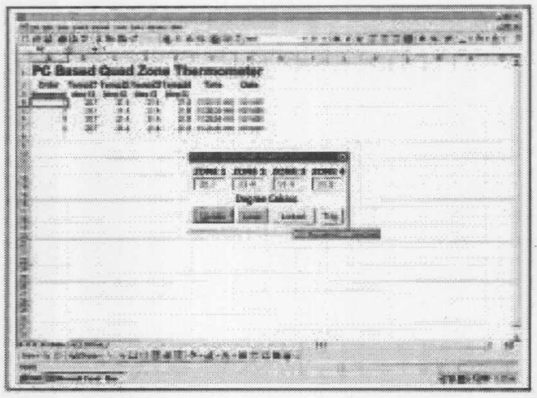

Figure 2 **The user form, which floats in front of an Excel spreadsheet, measures the temperature of four thermistors connected to LPT1.**

The user form displays a single quad-zone temperature measurement when you press the Update button on the user form. Measurement data links to the cells from columns A to G (named "data") in the spreadsheet when you press the Linked button. When you press the Loop button, the circuit samples measurement data in user-defined intervals. S_1 externally triggers measurement data if you press the Trig button. By using macros within Excel, all the graphing, analysis, and data-storage utilities common to Excel are available for familiar usage. The macros in the .xls listing contain the basic interface features for capturing the signal-conditioned thermistor-sensor signals. Within Module 1, the declaration of Input32.dll needs to include its directory path. The code for input/output of temperature data is within the user-form module.

The macros also include a software-calibration routine that steps users through a temperature-calibration sequence. With the thermistor inside a calibrated oven, you right-click on the user form to initiate calibration. The "cal" spreadsheet of **Figure 2** stores the raw calibration data. The "FitChart" chart plots this raw data and displays a fifth-order-polynomial trend-line equation. The user-form code uses the equation's coefficients to scale and display the temperatures in the user form.

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